RESIDUAL EFFECTIVENESS OF INSECTICIDES AGAINST SOIL-INHABITING INSECTS[1]

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INTRODUCTION

At the Sixtieth Annual Meeting of the American Association of Economic Entomologists, held December 13 to 16, 1948, at New York, N. Y., the guest speaker, F. P. Cullinan, Assistant Chief of the then Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, discussed "Some New Insecticides—Their Effect on Plants and Soils" (1).[3] The speaker noted that "Benzene hexahydrochloride and Chlordan like DDT are relatively stable in the soil. These chemicals present a problem if residues that prove harmful (to crops) remain in the soil." He told of tests being conducted at Beltsville, Md., on the effect on crops of "amounts representing the accumulation of a single season's application up to 10 and 20 times such amounts." Rather surprisingly, the extreme toxicity of DDT to cucumbers, which we have noted in Puerto Rico, was not mentioned, and, quite naturally, nothing was said about any of the even newer insecticides not available for test at that time.

The most important entomological implication in Cullinan's address was completely overlooked: that if insecticidal chemicals are "relatively stable in the soil" as judged by their effect on plants, they should also continue to be toxic to soil-inhabiting insects for an equally long period. The practical application of this proposition is that, if an application of 2 pounds per acre of the gamma isomer of benzene hexachloride or Aldrin has been made in a cane field to kill white grubs, not only are the grubs killed this year, but, depending on the stability of the insecticide, no grubs can develop in that field for many years thereafter. This is not only because no adults can develop in the treated field to start a new generation, but even females flying in from outside and laying eggs in soil that was treated a year earlier cannot develop a new infestation. The soil is permanently toxic to white grubs, or at least, so we hope.

Since the insecticides most effective in killing white grubs have been commercially available only a few years, one cannot prove at this time how long they will continue to be effective. But on the basis of implications in the above-mentioned address, the tests with soil insecticides at Río

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[3] Numbers in parentheses refer to Literature Cited, p. 114.

Piedras have been considered as merely started when proof of initial toxicity to insects is shown. It is of equal or possibly even greater importance to determine how long these treated soils will remain toxic, for if an insecticide continues to be toxic for some years after application, the soil to which it has been applied may prove to be permanently sterile to injurious insects. If this is indeed true, then the application of Aldrin or the gamma isomer of benzene hexachloride in sufficient quantity to kill white grubs may be regarded as a permanent improvement, and not merely temporary control that must be repeated each year.

EXPERIMENTAL PROCEDURE

Because of limited equipment and space, the samples of soils containing applications of insecticides that showed no indication of effectiveness at low concentrations had to be discarded. In retrospect, it might appear that the too prompt abandonment of DDD or TDE ("Rhothane") was an error, but with so many chemicals demanding test, only the soil samples mixed with the most promising could be retained. As previously noted, Cryolite at a rate of 100 pounds per acre, the Thiophos (Parathion), Toxaphene, Piperonyl cyclohexenone, Ryania, Methyl DDT or Methoxychlor, and zinc dimethyldithiocarbamate at 10 pounds per acre killed no grubs in 2 weeks, and were not tested further. Subsequently, Pinosylvin, Stilbene, Hyman 268 and Hyman 269, Dilan (the propane fraction), p-chlorophenyl-p-chlorobenzene sulfonate (Dow), l, l-di (2-hydroxy-3, 5-dichlorophenyl) 2,2,2-trichlorethane (Laurel Hill) and dimethyl-tetra-chlorphthalate (Penn Salt) were tested at rates of 10 pounds per acre, with little or no indication of value for soil-insect control except for Hyman 268 the first year it was tested.

That none of these chemicals was of value in the soil against soil-inhabiting insects should not be interpreted as implying ineffectiveness against some other kinds of insects, and they were tested against white grubs for this very reason: because they had proved (or at least indicated) conspicuous insecticidal value against other insects. The soil samples retained had been treated with Aldrin at rates of 100, 50, 25, 12, 6, 3, 1.5, 10, 5, 2, 1, and 0.5 pounds; with the gamma isomer of benzene hexachloride at 10, 5, 2, and 1 pounds-per acre; with Chlordan at rates of 10, 5, 2, and 1 pounds; and with DDT at 25, 20, and 12 pounds per acre. They were held so that the tests with endemic white grubs (*Phyllophaga* or *Lachnosterna* spp.) and weevil grubs (*Diaprepes abbreviatus* L.), as previously reported (2 and 3), could be repeated each year.

As these tests with insects require but a few months the soil samples were used in the meantime for testing their possible toxicity to plants, and corn, papaya, cucumber, sweetpotato, and banana plants as well as weeds,

were grown in them when no specific experiment with a cultivated crop was being conducted. They were generously watered most of the time, with no attempt to catch and reapply the run-off and prevent possible leaching-out of the insecticides. It should be remembered, however, that these insecticides are not water-soluble like most fertilizers, and possibly may be regarded as forming as permanent an addition to the soil as its original mineral constituents.

The original applications of insecticides to the soils were made on April 7, 1949, and each succeeding spring (1950, 1951, and 1952) field-collected white grubs from Aguirre or Isabela, in third instar, were placed in the soils, with corn and suitable amounts of water—but no additional insecticide—and re-examined at intervals of 2 to 3 weeks.

Examination consisted of dumping out all the earth and counting the surviving grubs, which were returned to the soil with fresh corn and generous watering to await a subsequent examination 2 or 3 weeks later. Subsequently each year small samples of this soil were placed in 2-ounce tin salve boxes, to which just-hatched grubs of *Diaprepes abbreviatus* L. were added in approximately equal numbers daily from the pool of those that had hatched overnight. The salve boxes were watched closely, fresh grubs were added daily, and they were dumped completely only when the germinating corn seedlings pushed off the covers. That is, the original experiments were duplicated each year, using the same methods as in the tests previously reported, and the same soil, but fresh grubs, fresh corn, and fresh water, and no additional insecticide.

In explanation and partial extenuation of the fact that the tests are not as complete and entirely comparable as might be wished, it should be noted that it is becoming increasingly difficult to obtain the requisite number of *Lachnosterna* white grubs because of natural control by toads, coupled with extensive commercial use of the chemicals which the initial experiments showed to be most effective in control. Only the most recent tests are here reported, superseding and making obsolete those of previous years.

RESULTS

By comparison with other effective chemicals the action of Chlordan on white grubs was surprisingly slow, 2 months elapsing before all the grubs were dead in the original tests in the soil treated with 10 and with 5 pounds per acre. Three years later proof of the effectiveness of Chlordan was so slow in becoming apparent that 2 weeks after the fresh grubs had been added, mortality was only one grub more when 10 pounds per acre were used than when 1 pound was used. These samples also had in them first-instar *Lachnosterna* grubs of which one more survived in the soil treated with 10 pounds per acre than in that treated with 1 pound per

acre. Indeed, the results were so inconclusive that applications of Hyman 269 were made to the same soil and the population was brought up to 10 third-instar *Lachnosterna* grubs in each sample, plus all the first-instar grubs that were available. Even a month after this addition the soil with 10 pounds of Chlordan applied 3 years ago, plus 10 pounds of Hyman 269 later, had eight *Lachnosterna* grubs in the third instar alive (although all in first instar were dead), and soil treated with 5 pounds of both chemicals had three *Lachnosterna* grubs in first instar alive and eight in third. A month later, one first-instar and six third-instar grubs were still alive in soil treated with 5 pounds per acre, and three third-instar *Lachnosterna* grubs were alive in that treated with 10.

In the original tests of soil mixed with Chlordan and just-hatched grubs of *Diaprepes abbreviatus* L., none survived at 10 and 5 pounds per acre, but "some grubs in the 1-pound-per-acre Chlordan had successfully transformed to the fourth instar by the twentieth day after hatching; by the thirty-second day, some had reached the fourth instar in the earth containing 2 pounds of Chlordan per acre." The results obtained in subsequent years were so remarkably similar as to indicate no loss in toxicity for vaquita grubs. These results with the two different kinds of grubs appear very inconsistent, indicating the slowness of action of Chlordan against white grubs, and against vaquita grubs, and a possibility of its being still as toxic as when originally applied.

To the soil samples to which, on April 7, 1949, 10, 5, 2, and 1 pound per acre of the gamma isomer of benzene hexachloride had been added, 10 third-instar *Lachnosterna* grubs were added, March 1, 1952, and on March 17, initial mortalities of 3 or 4 grubs in all except the 1-pound-per-acre sample were brought up to the full complement of 10 grubs. A month later, April 19, 6 grubs were missing in the 10-pound-, 3 in the 5-pound-, 2 in the 2-pound-, and none in the 1-pound-per-acre samples. Two months later, May 22, only 2 grubs remained alive in the 10-pound-per-acre and 3 in the 5-pound, but natural mortality may be considered responsible for the reduction to 6 in the 2-pound and 8 in the 1-pound-per-acre samples. Unfortunately, no first-instar *Lachnosterna* grubs had been available for test with gamma isomer, but obviously it was still toxic to the large third-instar grubs at the greater concentrations, even if doubtfully so at the minimum field applications that were initially made in Puerto Rico when the slight toxicity of the other isomers was not fully appreciated. The tests with just-hatched grubs of *Diaprepes abbreviatus* L. in the soil to which the gamma isomer of benzene hexachloride had been added indicated no increase in effectiveness, for the grubs grew and developed to the fifth instar at all concentrations, up to and including rates of 10 pounds per acre.

In the spring of 1952, 3 years after DDT had been applied to the soil at

rates of 25, 20, and 12 pounds per acre, a large number of *Ligyrus* grubs were sent in from Isabela, and to avoid wasting them, 10 were placed with each soil sample. Development of *Ligyrus* grubs is so rapid, however, that within little more than a week they began to pupate, and one even transformed into an adult, but none showed the effect of the insecticide. When the *Ligyrus* grubs and pupae were replaced with *Lachnosterna* grubs, all were alive a month later in the soil to which DDT was applied at rates of 12 and 20 pounds per acre, and 5 (half of them) in the 25-pound-per-acre samples: an almost exact reproduction of the results originally obtained when the application of DDT had been made to the soil.

Repeating the tests with just-hatched grubs of *Diaprepes abbreviatus* L., one survived to molt to the second instar in soil treated with 25 pounds of DDT per acre a month after it was placed with treated soil, but was dead a week later. By contrast, grubs developed to the fifth instar in the soil samples to which DDT was applied at rates of 20 and 12 pounds per acre, indicating that at this concentration DDT was ineffective in control. These results so closely paralleled those obtained originally that one may conclude that, as indicated by effects on soil-inhabiting insects, DDT suffers no loss of toxicity in 3 years when mixed with the soil. Cucumber plants which grew normally in all of the other samples, were conspicuously abnormal in the DDT-treated soils, and died a few weeks after germination. Thus, even at concentrations which are ineffective in insect control, the presence of DDT in the soil prevents the production of cucumbers.

The nontoxicity of DDT to *Ligyrus* grubs is not paralleled by the effect of Aldrin after 3 years in the soil with these grubs, for despite their rapidity of development, they suffered a high (but not entirely consistent) mortality at all concentrations of Aldrin, even at rates of as little as 1.5 pounds per acre. Both third- and first-instar grubs of *Lachnosterna* were used to determine the residual effect of Aldrin applied at rates of 100, 50, 25, 12, 6, 3, and 1.5 pounds per acre. Of the five first-instar *Lachnosterna* grubs placed with these samples on March 1, only one or two were still alive by March 17, at which time the quota was again brought up to five in each soil sample. By April 1, none remained alive in the samples treated at rates of 100 and 50 pounds per acre, and by April 19, none in any sample, apparently indicating that, even after 3 years in the soil, 1.5 pounds of Aldrin per acre will prevent white grub infestation. But so few third-instar grubs had died at this minimum concentration that their mortality may be attributed to natural causes. At 3 pounds per acre 4 grubs out of 10 died between March 1 and 17, and between April 1 and 19, 7 out of 10 died in soil treated at a rate of 3 pounds per acre, and none of the remaining 3 had survived a month later. At all the higher concentrations mortality was increasingly heavy in proportion to the amount of chemical present, and by May 22

was total, despite the two replacements to bring the complement up to the full strength of 10 third-instar grubs.

In the tests with just-hatched grubs of *Diaprepes abbreviatus* L., none survived when Aldrin was used at rates of 10, 5, 2, and 0.5 pounds per acre, and one grub transformed to the fourth instar in soil to which Aldrin had been added at a rate of 1 pound per acre 3 years before, but this grub died before molting to the fifth instar.

SUMMARY AND CONCLUSIONS

Results of tests with just-hatched grubs of *Diaprepes abbreviatus* L. as biological indicators of the residual effect of insecticides mixed with soil were much more consistent and showed little loss of toxicity in 3 years as compared with the tests using field-collected white grubs. Thus tests with third- or last-instar grubs of *Phyllophaga* (or *Lachnosterna*) *portoricensis* Smyth and *P. vandinei* Smyth, as well as with first-instar white grubs of these species, although not entirely conclusive, appear to indicate that, after being mixed with soil for 3 years, Chlordan is not nearly so toxic to white grubs as when originally applied. But the latest results with weevil grubs are almost identical with those of 3 years ago.

Even when freshly applied at the rate of 10 pounds per acre, the gamma isomer of benzene hexachloride did not kill just-hatched grubs of *Diaprepes abbreviatus* L., and cannot be recommended for field application to soils infested with them. This insecticide continued to be almost as effective against white grubs 3 years later as when originally applied to soil infested principally with them.

Aldrin appeared to be fully as effective against the weevil grubs of *Diaprepes abbreviatus* L., as when first applied 3 years earlier, and was found to be very toxic to the grubs of *Ligyrus* (which are of very minor economic importance). Even if it is less toxic to third-instar *Lachnosterna* white grubs at the concentrations recommended for original field application (2 pounds per acre) it will kill these grubs in the first-instar.

DDT appeared to be only slightly toxic to *Ligyrus* grubs as compared with Aldrin. For cucumbers and for the grubs of *Diaprepes abbreviatus* L., and the endemic species of *Lachnosterna*, DDT experienced no appreciable loss in toxicity in the soil with which it had been mixed 3 years earlier.

RESUMEN

Este trabajo aporta datos en relación con el efecto residual de algunos insecticidas sobre los insectos que viven bajo tierra.

Los resultados de los ensayos, en los cuales se usaron gusanos del *Diaprepes abbreviatus* L. recién salidas del huevo en el laboratorio, como indicadores biológicos del efecto residual de los insecticidas mezclados con tierra,

fueron más consistentes y el insecticida demostró una pérdida menor de toxicidad que cuando se usaron gusanos blancos del *Phyllophaga portoricensis* Smyth recogidas en los campos.

Según lo anterior, las pruebas con gusanos blancos del *Phyllophaga* (o *Lachnosterna*) *portoricensis* y con el *P. vandinei* Smyth, en su tercero o último estadio, como también en su primer estadio, aunque no fueron enteramente conclusivas, aparentan indicar que el clordano después de haber estadio mezclado con tierra por 3 años no resultó tan tóxico como cuando se aplicó originalmente.

Sin embargo, los últimos resultados con gusanos de la vaquita demostraron que el clordano conservó su efecto tóxico sin alteración alguna durante los 3 años de la prueba.

Aún cuando se aplicó por primera vez, a razón de 10 libras por acre, el isómero gamma del hexacloruro de benceno no pudo matar las gusanos recién salidas del *Diaprepes abbreviatus* L., por lo tanto no es recomendable su uso en los terrenos muy infestados por este insecto. Por otro lado, se notó que este insecticida conserva su poder tóxico por los 3 años cuando se trata de las gusanos del llamado gusano blanco de la caña.

El aldrín aparentemente fué tan eficaz para controlar las gusanos del *Diaprepes abbreviatus* al principio de las pruebas, al igual que a los 3 años de aplicado y también demostró ser muy tóxico a las gusanos blancos del *Ligyrus*, que es una plaga de menor importancia económica. Aún siendo menos tóxico al tercer estadio del *Lachnosterna*, si se usa la concentración de 2 libras por acre, el adrín mata las gusanos blancos de este insecto en su primer estadio.

Se observó que el DDT fué un poco menos tóxico a las gusanos blancos del *Ligyrus* que el aldrín. Cuando se combatieron loa gusanos del *Diaprepes abbreviatus* L. en pepinillos, como también las especies endémicas del *Lachnosterna*, no se apreció que el DDT perdiera su toxicidad original después de los 3 años de haberse aplicado al terreno.

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